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NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Water Storage and Related Physical Characteristics of Four Mineral Soils in North Central Minnesota

ABSTRACT. — Soil water storage in a 7.5 foot profile varied nearly 100 percent (7.9 to 15.5 inches) among four mineral soils ranging from a sand to sandy loam. Bulk density, size fractions, and four water retention values are tabulated for each horizon.

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Bulk density, size fractions, water retention, and hence water storage were determined for four soil types on the Marcell Experimental Forest in central Itasca County (ca. 47° 32′N;93° 28′W). These data were used in water budget studies for determining absolute changes in soil water storage and to interpret streamflow from experimental watersheds. Because of limited soils information in this area, these data should also be useful for correlating newly identified soil series as well as other water budget studies on similar soils.

The four soil types, Menahga loamy sand, Menahga sand, Warba sandy loam, and a taxadjunct[1] to Chisholm sandy loam, developed in two different parent materials.[2] The two Menahga types developed in noncalcareous, yellowish brown, coarse-textured drift; the Warba and taxadjunct to Chisholm types developed in slightly calcareous, light olive brown, medium-textured drift. The latter material was deposited over the coarse-textured drift so that soils developed in the medium-textured drift cover about 75 percent of the experimental forest. Soils developed in similar parent materials occur throughout north-central Minnesota.

Procedure

Soil profiles were selected, using a recent soil survey of the Experimental Forest[2], so that a large range of soil textures would be encountered. Bulk density was determined from four samples using either the clod method or 68.7 cc. split ring cores, depending on rockiness and density of the horizon. Values based on clod samples have been reduced by 12 percent to correct for interclod spaces. Total porosity was calculated with a particle density of 2.65.

Soil water retention values were determined from two samples using the pressure extraction technique. These values were corrected for the greater than 2 mm. fraction when ground samples of 2 mm. and less were used. When clod samples were used, no correction was necessary. In this study, water storage capacity is considered to be the difference between water retention values at 15 atm. and at either 0.06 atm. for coarse-textured soils or 0.10 atm. for fine-textured soils.

Soil textures were determined by dry sieving, wet sieving, residual, and Bouyoucos hydrometer methods for the greater than 2 mm., 2–.05 mm. (sand), .05–.002 mm. (silt), and the less than .002 mm. (clay) fractions, respectively.

[1] *Soils handled as taxadjuncts are considered adjuncts to, but not parts of, a mapping unit name. The taxadjunct to Chisholm sandy loam is enough like the Chisholm soil in morphology, composition, and behavior that little or nothing would be gained by adding a new series. (Personal communication, U.S.-D.A. Soil Conserv. Serv.)*

[2] *Paulson, Richard O. A soil survey of Marcell Experimental Forest. U.S.D.A. Soil Conserv. Serv. 34 p. 1968.*

Results and Discussion

The four soil types vary nearly 100 percent in water storage capacity. Periodic measurements of soil water to a depth of 10 feet show that the zone of significant water depletion and recharge extends to 7.5 feet under mature aspen stands (the dominate vegetation of the Marcell Experimental Forest and north-central Minnesota). Because of this, total water storage to a depth of 7.5 feet is used to compare the four soil types.

The Menahga loamy sand retains 7.9 inches while the Menahga sand retains 11.7 inches. The type names of the surface horizon appear to contradict the water storage values; however, these two profiles mark the textural extremes (coarse to fine) of the Menahga series. This contradiction can be explained by the distribution of two textural groups. First, the loamy sand contains 8 to 40 percent gravel (> 2 mm.) while the sand contains 0 to 6 percent. Second, the A2 horizon of the loamy sand contains 36 percent fine and very fine sand while the sand contains 54 percent. If the percentage of fine sand is high throughout the profile, it will yield higher water storage values than the type name (sand) would indicate; while the high percentage of gravel will yield lower water storage values than the type name (sandy loam) would indicate. The Warba sandy loam and taxadjunct to Chisholm retain 14.1[3] and 15.1 inches.

The data (tables 1-4) can be used to make gross estimates of water storage on similar soil series; however, because of the large difference occurring within one soil series (3.8 inches in Menahga) more accurate estimates are obtainable by using water storage values for horizons within a soil type.

Although absolute soil water storage values are not always necessary for a general water budget study, they are important for predicting and interpreting the hydrologic response of a watershed. For example, storm runoff is diminished by that part of the precipitation that satisfies the available soil water storage.

[3] *Since the Warba type was only sampled to a depth of 6.0 feet, the 5- to 6-foot water retention values were extrapolated to 7.5 feet. Auger samples show similar material extending 8 to 15 feet throughout the Warba type.*

Table 1. — Menahga loamy sand[1]

Horizon	Depth	Bulk density	Total porosity	Water by volume (percent) retained at-- .06 atm.	.10 atm.	.33 atm.	3 atm.	15 atm.	Water storage (inches) per-- Horizon	Foot	Soil fractions (percent) > 2 mm.	< 2 mm. Sand	Silt	Clay
	Feet		Percent											
A2	0.00-0.25	1.27	52	20.8	-	8.1	4.1	2.8	0.54	2.16	7.9	83.8[3]	13.1	3.1
B2	.25-1.10	1.50	43	16.2	7.1	5.5	3.5	2.4	1.41	1.66	26.3	75.8	19.8	4.4
B3	1.10-1.50	1.70	36	14.4	-	4.9	2.7	1.9	.60	1.50	20.6	92.0	5.3	2.7
B3	1.50-2.50	1.74	34	12.4	-	4.6	2.9	1.9	1.26	1.26	22.6	89.4	7.8	2.8
C	2.50-3.50	1.72	35	12.4	-	4.6	3.0	2.3	1.21	1.21	20.0	91.6	6.3	2.6
C	3.50-4.50	1.66	37	8.6	-	3.5	2.2	1.4	.86	.86	40.3	92.6	4.4	3.0
C	4.50-5.50	1.56	41	9.5	-	4.3	3.2	2.3	.86	.86	7.3	94.3	2.4	3.3
IIC2[2]	5.50-5.75	1.72	35	13.3	11.8	9.0	6.9	7.0	.19	.76	5.2	90.0	2.8	7.2
IIIC3[2]	5.75-5.90	1.55	42	-	36.6	33.0	24.0	18.1	.33	2.22	.3	41.3	16.2	42.5
IVC4	5.90-6.50	1.56	41	4.0	-	2.1	1.4	1.1	.21	.35	5.2	97.9	.7	1.4
IVC4	6.50-7.50	1.51	43	5.0	-	1.7	1.2	1.1	.47	.47	2.5	99.3	.6	.1
IVC4	7.50-8.50	1.47	45	2.9	-	1.2	1.2	1.0	.23	.23	1.5	99.6	.0	.4
IVC4	8.50-9.50	1.49	44	3.2	-	1.3	1.1	1.0	.26	.26	2.2	99.6	.2	.2
IVC4	9.50-10.5	1.49	44	3.1	-	1.3	1.0	.6	.30	.30	1.6	99.8	.1	.1

1/ Menahga series: sandy, mixed, frigid; Typic Udipsamment; Entisol.
2/ Bulk density and water retention values in these horizons are based on clod samples.
3/ Division of sand for this horizon is: V.C. 11.7, C. 34.6, M. 17.8, F. 28.2, V.F. 7.7 percent.

Table 2. — Menahga sand[1]

Horizon	Depth	Bulk density	Total porosity	Water by volume (percent) retained at-- .06 atm.	.10 atm.	.33 atm.	3 atm.	15 atm.	Water storage (inches) per-- Horizon	Foot	Soil fractions (percent) > 2 mm.	< 2 mm. Sand	Silt	Clay
	Feet		Percent											
A2	0.00-0.20	1.16	56	19.1	-	8.4	4.5	3.3	0.38	1.90	0	87.7 [3]	8.8	3.5
B2	.20-0.50	1.58	40	17.1	-	7.3	5.1	3.9	.48	1.60	0	92.8	4.8	2.4
B3	.50-1.50	1.51	42	11.5	-	2.9	2.3	1.9	1.15	1.15	0	98.6	.8	.6
C	1.50-2.50	1.58	40	14.4	-	3.8	1.6	1.3	1.57	1.57	0	97.2	1.4	1.4
C	2.50-3.50	1.58	40	14.7	-	3.2	2.1	1.3	1.60	1.60	0	97.1	1.9	1.0
C	3.50-4.50	1.60	40	15.0	-	2.7	2.6	1.6	1.61	1.61	0.2	96.2	2.6	1.2
C	4.50-5.50	1.61	39	-	15.8	8.2	6.3	3.8	1.44	1.44	1.0	85.9	9.2	4.9
C	5.50-6.50	1.70	36	-	18.4	9.6	7.5	5.0	1.60	1.60	5.7	84.8	10.2	5.0
IIC2 [2]	6.50-7.50	1.70	36	-	26.9	17.8	16.0	11.1	1.90	1.90	4.4	71.0	15.1	13.9
IIC2 [2]	7.50-8.50	1.72	35	-	25.2	23.2	17.0	12.6	1.51	1.51	8.2	61.0	24.4	15.1
IIC2 [2]	8.50-9.50	1.74	34	-	23.1	20.0	15.8	10.9	1.46	1.46	4.5	65.9	18.9	15.2
IIC2 [2]	9.50-10.0	1.60	40	-	32.5	27.2	22.2	14.6	1.71	2.42	2.8	37.9	38.6	28.5
IIIC3	10.00-10.5	1.50	43	4.4	3.7	1.5	1.3	1.2	.20	.40	4.2	97.3	1.7	1.0

1/ Menahga series: sandy, mixed, frigid; Typic Udipsamment; Entisol.
2/ Moisture retention values in these horizons are adjusted to a clod sample basis.
3/ Division of sand for this horizon is: V.C. 1.0, C. 10.5, M. 35.0, F. 47.6, V.F. 5.9 percent.

Table 3. — Warba sandy loam[1]

Horizon	Depth	Bulk density	Total porosity	Water by volume (percent) retained at-- .06 atm.	.10 atm.	.33 atm.	3 atm.	15 atm.	Water storage (inches) per-- Horizon	Foot	Soil fractions (percent) > 2 mm.	< 2 mm. Sand	Silt	Clay
	Feet		Percent											
A2	0.00-0.35	1.09	59	-	19.4	8.9	6.4	5.3	0.59	1.69	12.4	67.7 [3]	27.6	4.7
A22	.35-1.10	1.42	46	-	21.0	10.3	6.3	5.0	1.44	1.92	9.8	69.6	23.2	7.2
B21t [2]	1.10-1.50	1.59	40	-	25.8	23.6	21.4	5.7	.97	2.42	3.5	56.9	25.7	17.4
B22t [2]	1.50-2.30	1.57	41	-	31.9	29.3	21.9	19.0	1.24	1.55	4.3	41.4	28.3	30.3
B3 [2]	2.30-3.50	1.54	42	-	37.3	32.7	21.4	19.3	2.59	2.16	2.6	43.8	32.6	23.6
C [2]	3.50-5.00	1.58	40	-	35.3	25.8	23.3	19.8	2.79	1.86	3.1	43.5	29.3	27.2
C [2]	5.00-6.00	1.58	40	-	35.8	27.9	25.2	20.9	1.79	1.79	4.8	42.3	29.4	28.3

1/ Warba series: fine-loamy, mixed, frigid; Typic Eutroboralf, Alfisol.
2/ Bulk density and water retention values in these horizons are based on clod samples.
3/ Division of sand for this horizon is: V.C. 14.6, C. 25.3, M. 18.3, F. 29.5, V.F. 12.3 percent.

Table 4. — Taxadjunct to Chisholm sandy loam[1]

Horizon	Depth	Bulk density	Total porosity	Water by volume (percent) retained at-- .06 atm.	.10 atm.	.33 atm.	3 atm.	15 atm.	Water storage (inches) per-- Horizon	Foot	Soil fractions (percent) > 2 mm.	< 2 mm. Sand	Silt	Clay
	Feet		Percent											
A2	0.00-0.30	1.31	51	-	27.6	12.3	6.4	5.5	.79	2.63	5.3	66.6 [3]	24.9	8.5
B21irh	.30-0.50	1.36	49	-	21.4	10.4	5.6	3.6	.42	2.10	8.7	70.2	25.2	4.6
B22irh	.50-1.35	1.49	44	-	17.8	7.7	4.7	3.2	1.48	1.74	6.6	78.9	16.9	4.2
B3	1.35-1.80	1.58	40	-	11.4	4.4	2.6	1.8	.51	1.13	13.7	84.5	10.9	4.6
IIA'2t [2]	1.80-2.40	1.74	34	-	24.6	18.1	11.9	8.0	1.19	1.98	7.5	65.8	21.3	12.9
IIA'2t& IIB'2t [2]	2.40-4.00	1.65	38	-	30.2	29.7	22.1	11.9	3.52	2.20	3.8	45.8	24.7	29.5
IIB'2t [2]	4.00-5.00	1.58	40	-	35.8	27.5	24.2	18.6	2.07	2.07	3.4	48.7	24.5	26.8
IIB'3t [2]	5.00-7.25	1.57	41	-	37.1	29.2	20.5	18.1	5.13	2.28	3.6	45.9	24.7	29.5
IIC [2]	7.25-8.75	1.71	35	-	31.8	27.1	21.5	18.3	2.43	1.62	11.4	44.5	34.4	21.1
IIC [2]	8.75-10.50	1.71	35	-	33.1	24.8	21.0	19.1	2.94	1.68	8.3	45.2	39.2	15.6

1/ Taxadjunct to Chisholm series: fine-loamy, mixed, frigid, Typic Eutroboralf; Alfisol.
2/ Bulk density and water retention values in these horizons are based on clod samples.
3/ Division of sand for this horizon is: V.C. 14.3, C. 29.0, M. 20.0, F. 24.0, V.F. 12.7 percent.

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